

## **A Triple Redundant Latch Design with Storage Node Recovery**

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### **FIELD OF THE INVENTION**

[001] This invention relates generally to latch design. More particularly, this invention relates to improving soft error immunity in latches.

### **BACKGROUND OF THE INVENTION**

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[002] High-energy neutrons lose energy in materials mainly through collisions with silicon nuclei that lead to a chain of secondary reactions. These reactions deposit a dense track of electron-hole pairs as they pass through a p-n junction. Some of the deposited charge will recombine, and some will be collected at the junction contacts. When a particle strikes a sensitive region of a latch, the charge that accumulates could  
15 exceed the minimum charge that is needed to “flip” the value stored on the latch, resulting in a soft error.

[003] The smallest charge that results in a soft error is called the critical charge of the latch. The rate at which soft errors occur (SER) is typically expressed in terms of failures in time (FIT).

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[004] A common source of soft errors are alpha particles which may be emitted by trace amounts of radioactive isotopes present in packing materials of integrated circuits. “Bump” material used in flip-chip packaging techniques has also been identified as a possible source of alpha particles.

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[005] Other sources of soft errors include high-energy cosmic rays and solar particles. High-energy cosmic rays and solar particles react with the upper atmosphere generating high-energy protons and neutrons that shower to the earth. Neutrons can be particularly troublesome as they can penetrate most man-made

construction (a neutron can easily pass through five feet of concrete). This effect varies with both latitude and altitude. In London, the effect is two times worse than on the equator. In Denver, Colorado with its mile-high altitude, the effect is three times worse than at sea-level San Francisco. In a commercial airplane, the effect can  
5 be 100-800 times worse than at sea-level.

[006] Radiation induced soft errors are becoming one of the main contributors to failure rates in microprocessors and other complex ICs (integrated circuits). Several approaches have been suggested to reduce this type of failure. Adding ECC (Error Correction Code) or parity in data paths approaches this problem from an  
10 architectural level. Adding ECC or parity in data paths can be complex and costly.

[007] At the circuit level, SER may be reduced by increasing the ratio of capacitance created by oxides to the capacitance created by p/n junctions. The capacitance in a latch, among other types, includes capacitance created by p/n junctions and capacitance created by oxides. Since electron/holes pairs are created as  
15 high-energy neutrons pass through a p/n junction, a reduction in the area of p/n junctions in a latch typically decreases the SER. Significant numbers of electron/hole pairs are not created when high-energy neutrons pass through oxides. As a result, the SER may typically be reduced by increasing the ratio of oxide capacitance to p/n junction capacitance in a SRAM cell.

20 [008] There is a need in the art to reduce the SER in latches. An embodiment of this invention reduces the SER in latches while adding only a small increase in physical size of the latch and a small increase in the delay time through the latch. An embodiment of this invention also allows recovery of several storage nodes disturbed by a soft error event.

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## **SUMMARY OF THE INVENTION**

[009] In a preferred embodiment, the invention provides a circuit and method  
5 for a smaller and faster triple redundant latch with storage node recovery. An input  
driver is connected to the input of three transfer gates. The output of each transfer  
gate is connected to a separate output of one of three feedback inverters. The transfer  
gates are controlled by two control inputs. The inputs of the three feedback inverters  
are connected the output of the forward inverter/majority voter. The output from each  
10 of the three feedback inverters are inputs to the forward inverter/majority voter. The  
output of the forward inverter/majority voter is connected to the input of the output  
driver. The output of the output driver is the output of the triple redundant latch.

[010] Other aspects and advantages of the present invention will become  
apparent from the following detailed description, taken in conjunction with the  
15 accompanying drawings, illustrating by way of example the principles of the  
invention.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

[011] Figure 1 is a schematic of a triple redundant latch. Prior Art

[012] Figure 2 is a block diagram of an improved triple redundant latch with  
storage node recovery.

[013] Figure 3 is a schematic of an improved triple redundant latch with storage node recovery.

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#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

[014] Figure 1 is a schematic of a triple redundant latch. The input, 100, to the triple redundant latch is connected to the input of transfer gates, TG1, TG2, and TG3. Control signal, 102, is connected to transfer gates, TG1, TG2, and TG3. Control signal, 102, controls when the signal on the input of transfer gates, TG1, TG2, and TG3 is transferred to the outputs, 104, 106, and 108 of transfer gates, TG1, TG2, and TG3 respectively. The signal presented to outputs, 104, 106, and 108, is stored in LATCH1, LATCH2, and LATCH3 respectively.

[015] After control signal, 102, is turned off, the signal on LATCH1 drives the input of inverter, INV1. After control signal, 102, is turned off, the signal on LATCH2 drives the input of inverter, INV2. After control signal, 102, is turned off, the signal on LATCH3 drives the input of inverter, INV3. The output, 110, of inverter, INV1, drives an input to AND1 and an input to AND2. The output, 112, of inverter, INV2, drives an input to AND1 and an input to AND3. The output, 114, of inverter, INV3, drives an input to AND2 and an input to AND3. The output, 116, of AND1 drives an input of OR1. The output, 118, of AND2 drives an input of OR1. The output, 120, of AND3 drives an input of OR1. The output of the triple redundant latch is the output, 122 of OR1.

[016] A triple redundant latch reduces soft errors by storing the same data in three different latches. For example, when the control signal, **102** is on, a logical high value may be driven from the inputs, **100**, of transfer gates, **TG1**, **TG2**, and **TG3** to the outputs, **104**, **106**, and **108**, of transfer gates, **TG1**, **TG2**, and **TG3** respectively.

5 After turning control signal **102** off, a logical high value is stored in latches, **LATCH1**, **LATCH2**, and **LATCH3**. The stored logical high value on **LATCH1** drives the input of inverter, **INV1**, and produces a logical low value on the output, **110**, of inverter, **INV1**. The stored logical high value on **LATCH2** drives the input of inverter, **INV2**, and produces a logical low value on the output, **112**, of inverter,  
10 **INV2**. The stored logical high value on **LATCH3** drives the input of inverter, **INV3**, and produces a logical low value on the output, **114**, of inverter, **INV3**.

[017] Since the output, **110**, **112**, and **114** of inverters, **INV1**, **INV2**, and **INV3**, respectively, are low, all the inputs, **110**, **112**, and **114** to **AND1**, **AND2**, and **AND3** respectively are a logical low value. Since all the inputs, **110**, **112**, and **114**,  
15 to **AND1**, **AND2**, and **AND3** respectively are a logical low value, the output, **116**, **118**, and **120** of **AND1**, **AND2**, and **AND3** respectively are a logical low value. Since the output, **116**, **118**, and **120** of **AND1**, **AND2**, and **AND3**, respectively are a logical low value, all the inputs of **OR1** are a logical low value. Since all the inputs, **116**, **118**, and **120** to **OR1** are logical low value, the output, **122**, is logical low value.

20 [018] If a soft error occurs, for example, in **LATCH2**, and changes the stored logical value from a logical high value to a logical low value, a logical low value is now presented to the input, **106**, of inverter, **INV2**. The output, **112**, of inverter, **INV2**, presents a logical high value to an input of **AND1** and **AND3**. Since, in this example, the other input, **110** to **AND1** and the other input, **114**, to **AND3**, is a logical  
25 low value, the output, **116** and **120** of **AND1** and **AND3** respectively remains a

logical low value and the output, **122**, does not change. This example illustrates how a single soft error in one latch does not change the original stored value in a triple redundant latch.

[019] As a further example, assume, in addition to the soft error in **LATCH2**,  
5 there is an additional soft error in **LATCH3**. Now, the input, **108**, to inverter, **INV3**, is a logical low value and as a result, the output, **114**, of inverter, **INV3**, is a logical high value. A logical high value is now presented to an input, **114**, of **AND2**, and to an input, **114**, of **AND3**. Since a logical low and logical high value are presented on the inputs of **AND1**, the output, **116** of **AND1** is still a logical low value. Since a  
10 logical low and logical high value are presented on the inputs of **AND2**, the output, **118** of **AND2** is still a logical low value. However, since inputs, **112** and **114**, to **AND3** are a logical high value, the output, **120**, is a logical high value. Since input, **120**, to **OR1** is a logical high value, the output, **122**, changes from a logical low value to a logical high value. This example illustrates how soft errors in two latches of a  
15 triple redundant latch does change the original stored value of the triple redundant latch.

[020] A triple redundant latch prevents a single soft error from changing the original value stored in the latch. However, this comes at the cost of additional circuitry which results in a physically larger latch. In addition, a triple redundant may  
20 introduce time delay in the delay path of the latch. As consequence, a triple redundant latch is usually larger and slower than a single latch.

[021] Figure 2 is a block diagram of a triple redundant latch with storage node recovery. An input driver, **INDRV**, receives a signal at its input, **200**, and drives a signal from its output, **202**, to the inputs, **202**, of transfer gates, **TG1**, **TG2**, and **TG3**.  
25 In addition, a tristatable input inverter, a cross-coupled NAND gate, and a cross-

coupled NOR gate may be used in place of a transfer gate. If the control signals, **204** and **206**, are on, the signal at the input, **202**, of transfer gates, **TG1**, **TG2**, and **TG3**, is transferred to the output, **208**, of transfer gate, **TG1**, the output, **210**, of transfer gate, **TG2**, and the output, **212** of transfer gate, **TG3**. The logical value presented on storage nodes, **208**, **210**, and **212** are also presented as inputs to the forward inverter/majority voter, **FWINV/MV**.

[022] The forward inverter/majority voter, **FWINV/MV**, as a result of the logical value presented on inputs **208**, **210**, and **212**, outputs a logical value, **214**, of the opposite sense of the logical value presented on the inputs, **208**, **210**, and **212**. The output, **214**, of the forward inverter/majority voter, **FWINV/MV**, drives the input of each feedback inverter, **FBINV1**, **FBINV2**, and **FBINV3**. In addition, a tristatable inverter may be used in place of a feedback inverter. The output of each feedback inverter, **208**, **210**, and **212**, feeds back the same logical value originally presented at the outputs, **208**, **210**, and **212**, of transfer gates **TG1**, **TG2**, and **TG3** respectively. The combination of feedback inverters, **FBINV1**, **FBINV2**, and **FBINV3** along with the forward inverter/majority voter, **FWINV/MV**, create a latch, **226**, where nodes **208**, **210**, and **212** are storage nodes.

[023] After control inputs, **204** and **206**, are turned off, the latch, **226**, retains the original signal logical value presented by transfer gates, **TG1**, **TG2**, and **TG3**. The logical value stored on storage nodes **208**, **210**, and **212** are connected to the inputs of the forward inverter/majority voter, **FWINV/MV**. The output, **214**, of the forward inverter/majority voter, **FWINV/MV**, drives the input, **214**, of the output driver, **OUTDRV**. The output, **224**, of the output driver, **OUTDRV**, is the output of the triple redundant latch.

[024] As an example of how redundancy applies for this embodiment, assume that a logical high value is stored. Storage nodes **208**, **210**, and **212** each have a logical high value stored in this example. Storage node **214** holds a logical low value. If, in this example, storage node **208** is disturbed by a soft error event and the value on node **208** changes to a logical low value, a logical low value is presented to an input of the forward inverter/majority voter, **FWINV/MV**. Since the forward inverter/majority inverter, **FWINV/MV**, still has two inputs, **210** and **212**, at a logical high value, the output of the forward inverter/majority inverter, **FWINV/MV**, remains a logical low value as it was before the soft error event. Since node **214** remains a logical low value, the input of feedback inverter, **FBINV1**, is driven by a logical low value. Since the input, **214**, of feedback inverter, **FBINV1**, is driven by a logical low value, the output, **208**, of the feedback inverter, **FBINV1**, is driven back to its original logical high value. The storage node, **208**, is recovered.

[025] If, however, in this example, a soft error event changes the values stored on nodes **208** and **210** at nearly the same time, the triple redundant latch will change from its original value. If a soft error event, at nearly the same time, changes the logical values stored on nodes **208** and **210**, from a logical high values to a logical low values, the inputs, **208** and **210**, into the forward inverter/majority voter, **FWINV/MV**, change from logical high values to logical low values. As a result of having logical low values on the inputs, **208** and **210**, the majority vote is a logical low value. As a result, the logical value stored on node **214** is changed from the original logical low value to a logical high value. Since the logical value stored on node **214** is high, the input to all three feedback inverters, **FBINV1**, **FBINV2**, and **FBINV3**, is a logical high value. Because the input to all three feedback inverters, **FBINV1**, **FBINV2**, and **FBINV3**, is a logical high value, the output, **208**, **210**, and



212 of the feedback inverters, **FBINV1**, **FBINV2**, and **FBINV3** respectively, are driven to a logical low value. In this example, the original value stored in the triple redundant latch is changed from a logical high value to a logical low value.

[026] In addition to improving the soft error rate of a latch, the triple  
5 redundant latch shown in Figure 2, also reduces the physical size of a triple redundant latch because it uses fewer transistors. The triple redundant latch shown in Figure 2 also reduces the delay time through a triple redundant latch because the number of logic delays is reduced.

[027] Figure 3 is a schematic of an improved triple redundant latch with  
10 storage node recovery. Figure 3 contains the same basic blocks that Figure 2 contains; input driver, **INDRV**, transfer gate 1, **TG1**, transfer gate 2, **TG2**, transfer gate 3, **TG3**, feedback inverter, **FBINV1**, feedback inverter, **FBINV2**, feedback inverter, **FBINV3**, forward inverter/majority voter, **FWINV/MV**, and output driver, **OUTDRV**. An embodiment of an input driver, **INDRV**, for the triple redundant  
15 latch contains a PFET, **MP1** and an NFET, **MN1**. In this embodiment, the source of the PFET, **MP1** is connected to **VDD**, the drain, **302**, is connected to the output of the input driver, **INDRV**, and the drain of the NFET, **MN1**. The gates, **300**, of the PFET, **MP1**, and the NFET, **MN1**, are connected to the input of the input driver, **INDRV**. The source of the NFET, **MN1**, is connected to **GND**.

20 [028] An embodiment of a transfer gate 1, **TG1**, for the triple redundant latch contains a PFET, **MP2** and an NFET **MN2**. In this embodiment, the drains of PFET, **MP2**, and NFET, **MN2**, are connected to the input, **302**, of transfer gate 1, **TG1**. The sources of PFET, **MP2**, and NFET, **MN2**, are connected to the output, **308**, of transfer gate 1, **TG1**. The gate of PFET, **MP2**, is connected to the control input, **306**, of

transfer gate 1, **TG1**. The gate of NFET, **MN2**, is connected to the control input, **304**, of transfer gate 1, **TG1**.

[029] An embodiment of a transfer gate 2, **TG2**, for the triple redundant latch contains a PFET, **MP3** and an NFET **MN3**. In this embodiment, the drains of PFET, **MP3**, and NFET, **MN3**, are connected to the input, **302**, of transfer gate 2, **TG2**. The sources of PFET, **MP3**, and NFET, **MN3**, are connected to the output, **310**, of transfer gate 2, **TG2**. The gate of PFET, **MP3**, is connected to the control input, **306**, of transfer gate 2, **TG2**. The gate of NFET, **MN3**, is connected to the control input, **304**, of transfer gate 2, **TG2**.

[030] An embodiment of a transfer gate 3, **TG3**, for the triple redundant latch contains a PFET, **MP4** and an NFET **MN4**. In this embodiment, the drains of PFET, **MP4**, and NFET, **MN4**, are connected to the input, **302**, of transfer gate 3, **TG3**. The sources of PFET, **MP4**, and NFET, **MN4**, are connected to the output, **312**, of transfer gate 3, **TG3**. The gate of PFET, **MP4**, is connected to the control input, **306**, of transfer gate 3, **TG3**. The gate of NFET, **MN4**, is connected to the control input, **304**, of transfer gate 3, **TG3**.

[031] An embodiment of feedback inverter 1, **FBINV1**, for the triple redundant latch contains PFET, **MP5**, and NFET, **MN5**. In this embodiment, the gate of PFET, **MP5**, and the gate of NFET, **MN5**, is connected to input, **314**, of feedback inverter 1, **FBINV1**. The drain of PFET, **MP5**, and the drain of NFET, **MN5**, is connected to the output, **308**, of feedback inverter 1, **FBINV1**. The source of PFET, **MP5** is connected to **VDD**. The source of NFET, **MN5**, is connected to **GND**.

[032] An embodiment of feedback inverter 2, **FBINV2**, for the triple redundant latch contains PFET, **MP6**, and NFET, **MN6**. In this embodiment, the gate of PFET, **MP6**, and the gate of NFET, **MN6**, is connected to input, **314**, of feedback

inverter 2, **FBINV2**. The drain of PFET, **MP6**, and the drain of NFET, **MN6**, is connected to the output, **310**, of feedback inverter 2, **FBINV2**. The source of PFET, **MP6** is connected to **VDD**. The source of NFET, **MN6**, is connected to **GND**.

[033] An embodiment of feedback inverter 3, **FBINV3**, for the triple  
5 redundant latch contains PFET, **MP7**, and NFET, **MN7**. In this embodiment, the gate of PFET, **MP7**, and the gate of NFET, **MN7**, is connected to input, **314**, of feedback inverter 3, **FBINV3**. The drain of PFET, **MP7**, and the drain of NFET, **MN7**, is connected to the output, **312**, of feedback inverter 3, **FBINV3**. The source of PFET, **MP7** is connected to **VDD**. The source of NFET, **MN7**, is connected to **GND**.

[034] An embodiment of a forward inverter/majority voter, **FWINV/MV**, for  
10 the triple redundant latch contains PFET, **MP8**, PFET, **MP9**, PFET, **MP10**, PFET, **MP11**, PFET, **MP12**, NFET, **MN8**, NFET, **MN9**, NFET, **MN10**, NFET, **MN11**, and NFET, **MN12**. In this embodiment, the sources of PFET, **MP8**, PFET, **MP10**, and PFET, **MP12**, are connected to **VDD**. In this embodiment, the sources of NFET, **MN9**, NFET, **MN11**, and NFET, **MN12**, are connected to **GND**. The drain of PFET, **MP8**, and the source of PFET, **MP9** are connected to node, **316**. The drain of PFET, **MP10**, the drain of PFET, **MP12**, and the source of PFET, **MP11** are connected to node, **320**. The drain of NFET, **MN9**, and the source of NFET, **MN8** are connected to node, **318**. The drain of NFET, **MN11**, the drain of NFET, **MN12**, and the source  
15 of NFET, **MN10** are connected to node **322**. The drains of PFET, **MP9**, PFET, **MP11**, NFET, **MN8**, and NFET, **MN10** are connected to the output, **314**, of the forward inverter/majority voter, **FWINV/MV**. The gates of PFET, **MP8**, PFET, **MP10**, NFET, **MN9**, and NFET, **MN11**, are connected to an input, **308**, of the forward inverter/majority voter, **FWINV/MV**. The gates of PFET, **MP9**, PFET, **MP12**, NFET, **MN8**, and NFET, **MN12**, are connected to an input, **310**, of the  
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forward inverter/majority voter, **FWINV/MV**. The gates of PFET, **MP11**, and NFET, **MN10**, are connected to an input, **312**, of the forward inverter/majority voter, **FWINV/MV**.

[035] An embodiment of an output driver, **OUTDRV**, for the triple redundant latch contains a PFET, **MP13** and an NFET, **MN13**. In this embodiment, the source of the PFET, **MP13** is connected to **VDD**, the drain, **324**, is connected to the output of the output driver, **OUTDRV**, and the drain of the NFET, **MN13**. The gates, **314**, of the PFET, **MP13**, and the NFET, **MN13**, are connected to the input, **314**, of the input driver, **OUTDRV**. The source of the NFET, **MN13**, is connected to **GND**.

[036] Figure 3 is a schematic of an improved triple redundant latch. An input driver, **INDRV**, receives a signal at its input, **300**, and drives a signal from its output, **302**, to the inputs, **302**, of transfer gate 1, **TG1**, transfer gate 2, **TG2**, and transfer gate 3, **TG3**. If control signal, **304** is a logical high value and control signal, **306**, is a logical low value, the signal at the input, **302**, of transfer gate 1, **TG1**, transfer gate 2, **TG2**, and transfer gate 3, **TG3** is transferred to the output, **308**, of transfer gate 1, **TG1**, the output, **310**, of transfer gate 2, **TG2**, and the output, **312**, of transfer gate 3, **TG3**.

[037] The signal transferred to nodes **308**, **310**, and **312** is also present on the inputs of the forward inverter/majority voter, **FWINV/MV**. Since the inputs, **308**, **310**, and **312** are the same sense, the opposite sense is presented on the output, **314**, of the forward inverter/majority voter, **FWINV/MV**. The output of the forward inverter/majority voter, **FWINV/MV**, is presented on the input, **314**, of all three feedback inverters, **FBINV1**, **FBINV2**, and **FBINV3**. The outputs, **308**, **310**, and **312**, of the feedback inverters, **FBINV1**, **FBINV2**, and **FBINV3** respectively reinforce the original logical value stored on nodes **308**, **310**, and **312**. The

combination of feedback inverters, **FBINV1**, **FBINV2**, **FBINV3**, and forward inverter/majority voter, **FWINV/MV**, form a latch, **LATCH1**, **326**.

[038] After control input, **304**, is driven to a logical low value, and control input, **306**, is driven to a logical high value, **LATCH1**, **326**, stores the original logical value stored on nodes **308**, **310**, and **312**. The original logical value stored on nodes **308**, **310** and **312**, are applied to the inputs, **308**, **310**, and **312** of the forward inverter/majority voter, **FWINV/MV**. If none of the nodes, **308**, **310**, and **312**, is disturbed, then a signal of the opposite sense is presented on the output, **314**, of the forward inverter/majority voter, **FWINV/MV**.

[039] For example, if a logical high value is stored on nodes **308**, **310**, and **312**, then a logical low value is presented on the output, **314**, of the forward inverter/majority voter, **FWINV/MV**. The logical low value on the output, **314**, of the forward inverter/majority voter, **FWINV/MV**, is then presented on the inputs, **314**, of each feedback inverter, **FBINV1**, **FBINV2**, and **FBINV3**. In this example, the outputs, **308**, **310**, and **312**, of feedback inverters, **FBINV1**, **FBINV2**, and **FBINV3**, respectively, reinforce the original logical high value stored on nodes **308**, **310**, and **312**. In this example, the logical low value presented to input, **314**, of the output driver, **OUTDRV**, is driven to a logical high value at the output, **324**, of the output driver, **OUTDRV**.

[040] If in this example where a logical high value is stored on nodes, **308**, **310**, and **312**, node **308** is changed to a logical low value by a soft error event, a logical low value is then presented to input, **308**, of the forward inverter/majority voter, **FWINV/MV**. Inputs, **310** and **312**, remain a logical high value. Since inputs, **310** and **312**, are logical high values and the majority, the output, **314**, of the forward inverter/majority voter, **FWINV/MV** remains a logical low value. Because the

output, 314, of the forward inverter/majority voter, **FWINV/MV**, is a logical low value, the output, 308, of feedback inverter, **FBINV1**, is driven to a logical high value. The logical value on node 308 is recovered from the disturbed value of a logical low value to the original logical high valued stored on it. In this example, a  
5 single soft error did not change the original value stored in the triple redundant latch.

[041] If, however, a soft error event changes the value stored on node, 308 and node, 310, at nearly the same time, the triple redundant latch will change from its original value. For example, if a logical high value is stored on nodes 308, 310, and 312, a logical low value is presented on the output, 314, of the forward  
10 inverter/majority voter, **FWINV/MV**. If a soft error event changes the logical value stored on nodes, 308 and 310, from a logical high value to a logical low value at nearly the same time, inputs, 308 and 310, into the forward inverter/majority voter, **FWINV/MV**, change from logical high values to logical low values. Since inputs, 308 and 310, of the forward inverter/majority voter, **FWINV/MV**, are a logical low  
15 value, the majority vote is low and the output, 314, of the forward inverter/majority voter, **FWINV/MV**, is a logical high value. Since the output, 314, is a logical high value, the values stored on nodes 308, 310, and 312 are changed to a logical low value. In this example, the original value stored in the triple redundant latch is changed from a logical high value to a logical low value.

20 [042] If two soft error events occur far enough apart in time, nodes 308, 310, and 312 will all retain their original logical values. For example, if a soft error event changes node 308 from a logical high value to a logical low value, and a second soft error event doesn't disturb node 310 until the triple redundant latch recovers node 308, the node, 310, disturbed by a second soft error event will also be recovered to a  
25 high logical value. In this example, all nodes, 308, 310, and 312 will retain their

original logical high value after these two soft error events. An advantage of this latch is that the value stored may be held for years without being disturbed. For example, a gated latched may store a value during power up of a system. This value may not change until the system is powered down again. In some cases, a system  
5 may not be powered down for years and a latch may not be refreshed during this time.

[043] The soft error rate for this triple redundant latch is lower when implemented using CMOS (Complementary Metal Oxide Semiconductor) on a SOI (Silicon On Insulator) substrate than when implemented using CMOS on semiconductor substrate. Because the failure mechanism for CMOS on a SOI is  
10 different from the failure mechanism for CMOS on a semiconductor substrate when using this triple redundant latch, a lower soft error rate may be achieved when designing this triple redundant latch using CMOS on SOI. The failure mechanism for the triple redundant latch when using CMOS on a semiconductor substrate is a storage node effect. Electron-hole pairs may create charge that can diffuse to a storage node  
15 and change the logical value on the node. The failure mechanism for a triple redundant latch when using CMOS on SOI is a transistor effect. When radiation strikes one or more transistors in the latch, one or more bipolar transistors may be triggered with enough gain to turn one or more FETs on. If enough FETs are turned on the storage node, 314, shown in Figure 3 may change its logical value.

20 [044] In addition to improving the soft error rate of a latch, the triple redundant latch shown in Figure 3, also reduces the physical size of a triple redundant latch because it uses fewer transistors. The triple redundant latch shown in Figure 3 also reduces the delay time through a triple redundant latch because the number of logic delays is reduced.

[040] The foregoing description of the present invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and other modifications and variations may be possible in light of the above teachings. The embodiment was  
5 chosen and described in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and various modifications as are suited to the particular use contemplated. It is intended that the appended claims be construed to include other alternative embodiments of the invention except insofar as limited by  
10 the prior art.